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ABSTRACT

Education can profit significantly from hypermedia and e-technologies. However, in the authors' experience, the majority of students having the choice of learning on the computer or from a printed script or book prefer the latter when it comes to "challenging" formal domains. For online learning material to be successful, its structure and presentation have to reflect the characteristics of hypermedia and the Web. This paper presents a model of the didactical structure of online learning content based on methods of instructional design. The model specifically addresses two major problems of the Web medium for learning: loss of overview due to low information density of the medium and short attention spans due to "fast fatigue" of perception. The model serves as a framework which guides the author in structuring even abstract and complex content such that it can be efficiently learned on the Web. The model is the basis of how 12 German universities structure their content in the joint project WWR (Wissenswerkstatt Rechensysteme (Knowledge Factory for Computing Systems)), which aims at providing a pool of 150 XML-based online learning modules in technical computer science. (Contains 23 references.) (Author)

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Presenting Complex e-Learning Content on the Web: A Didactical Reference Model

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Abstract: Education can profit significantly from hypermedia und e-technologies. However, in our experience the majority of students having the choice of learning on the computer or from a printed script or book prefer the latter when it comes to "challenging" formal domains. For online learning material to be successful its structure and presentation have to reflect the characteristics of hypermedia and the web. This paper presents a *model* of the *didactical structure* of online learning content based on methods of instructional design. The model specifically addresses two major problems of the medium web for learning: *loss of overview* due to low information density of the medium and *short attention spans* due to fast fatigue of perception. The model serves as a framework which guides the author in structuring even abstract and complex content such that it can be efficiently learned on the web. The model is the basis of how 12 German universities structure their content in the joint project WWR (Wissenswerkstatt Rechensysteme – Knowledge Factory for Computing Systems) which aims at providing a pool of 150 XML-based online learning modules in technical computer science.

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1. Introduction

In our experience from current e-learning projects [NE02, LA02, WWR02] e-learning needs to take different learning styles into account to be successful. Thus in all of these projects we decided to publish the course material in at least two formats: (1) as a web- based e-learning course, (2) as a traditional printed script. However, internal evaluations have shown that the majority of students prefer the print medium, when it comes to "challenging" complex or abstract subjects which are typically taught in higher maths and computer science education.

This observation is not just coincidental. We identified two major disadvantages of the medium web for learning formal material:

- Relatively low information density: the amount of information which can be presented on the screen is limited as compared to print media. This leads to a quick **loss of overview**, when the presented material is complex.
- Non-optimal learning environment: research results show, that the perception tires out quickly when the recipient has to grasp a large amount of new information on the screen [KS89]. As a result, authors of online material have to cope with particularly **short attention spans**.

To tackle these problems we developed a didactically motivated information model for e-learning modules. Our model has proven useful for (1) the story board-based **specification** of e-learning modules, in particular the definition of forms, (2) the **implementation** of modules, specifically the enhancement of XML languages in terms of didactical structures, (3) the development of an appropriate **presentation** framework supporting the learner's orientation and navigation. [WSK02, SFB99].

The rest of the paper is organized as follows: In section 2 we discuss the scientific background of our model, section 3 presents our model in detail, section 4 discusses related work and section 5 concludes with a summary of our achievements.

2. Prerequisites and Foundations

The model presented in this paper is based on the didactical framework of Instructional Design (ID) [M94]. The focus is on the analysis and design phase of ID (i.e. preparing the learning content and planning the instructional method and media) rather than on the other processes of ID.

Prerequisites of the reference model

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The model concentrates on the structure and optimal presentation of learning material on the web with minimum requirements regarding the technical and social learning environment. The basic assumptions are as follows:
Domain: Our goal is to provide online modules which accompany university lectures in technical subjects (such as maths, computer science). The domain to be taught is well structured. Scientifically founded expert models exist and are taught to the students. A collection of objectives is given (e.g. based on examination regulations) or can easily be defined.
Target Group: The target group is relatively homogeneous and their profile (characteristics, pre-knowledge) well known. Our model does not (yet) address the personalized presentation of course material with respect to different individual profiles.
Learning Situation: The main purpose of the learning modules considered here is the support of self-motivated study and unsupervised revision before exams. It is further assumed that the individual study is the primary learning form. Students may of course build learning communities on their own initiative. However, group work and communication processes are not specifically addressed in our model. In this sense our model could be seen as a part of a larger complete model [SFB99, K01].
Medium: On the technical side the minimum requirement is a standalone standard PC. A permanent internet connection, special tools or learning environments may be useful for certain modules, but are not imposed by our model.

Instruction Models

Several learning theories have been discussed in the literature as a basis for the instructional method: The major strands are **Behaviourism**, **Cognitivism**, and **Constructivism** [GCR96, M94, D92].
The constructivist learning theory is a modern approach for designing learning material as it stresses the **active individual exploration** of the domain to be studied. However, we have chosen the cognitive approach as the basis for the structural model:

- The focus is on lectures based on scientifically founded complex expert models. It is mandatory that students understand the subject in detail and on a rather formal level. The course leads the students to a high level of mastery of **predefined** objectives.
- The learner needs to receive sufficient guidance by the predefined structure and presentation of the course material since we assume unsupervised study as the main purpose.
- Even cognitively designed web material does not necessarily limit individual, active exploration when presented in conjunction with free navigation support, search facilities and integration of runtime systems (such as web-interfaces to databases, applets simulating algorithms…).

Structural requirements for online material

We have selected and categorised the guidelines from software ergonomics and media didactics related to the identified major problems of web based learning [KS88, M93, Mea96, MDC84, B97]:
Loss of overview:
1) *First present the overview then the details.*
2) *Restrict yourself to significant information.*
3) *Offer orientation opportunities to the user.*
Short attention spans:
4) Make the (re-)start of learning easy: *provide contextual information.*
5) Keep in mind, the learner will get tired quickly: *don't present too much at once.*
6) However, try to prevent the user from getting tired quickly: *activate the learner regularly.*
Why are these guidelines difficult to meet? In conjunction with formal content they lead to the following contradictive requirements:

- *Formal precision and completeness of the material vs. lower attentiveness of the recipient on the web.* Higher education often requires completeness of the material regarding formal definitions, arguments, proofs. However, when presented on the web in the wrong way certain formal material may constitute an unnecessary obstacle for the recipient's overview and flow of learning.
- *Fine-granular structure of material vs. avoiding loss of overview.* Due to the low information density the chunks of information presented on the web need to be relatively small. This leads to a fine-granular and deeper hierarchical structure as compared to print material and makes it harder for the student to keep the overall overview.

Material which is structured according to our model will automatically fulfil the guidelines stated above and thus also solve the stated contradictions.

3. Didactical Structures of Online Material – Information Model

Next, we present the model of didactical structures of courseware. The main emphasis is on the micro-structure level of *learning resources* (in contrast to macro-structures such us curricula, courses) [AD01].

Hierarchical sequential organisation

Basic entities of our model are the learning module and the learning unit.
Learning modules present instructions for learning an expert model in a single, self-contained and complete area of a certain domain. They can be (re-)used in several different courses/curricula. In our model we assume that a learning module requires 2 to 10 hours of study. Learning modules are described by metadata and organised in **sections** which represent the hierarchy of topics to be taught in the module.
A **learning unit** is a special type of section. It represents all the material and instructions required for one single learning session. The required study time is suggested to be 45 minutes.
Learning units lead the learner from one level of expertise to the next in one or more **learning steps**. Learning steps constitute one part of the learning unit's complex internal structure which is presented in the following sections.

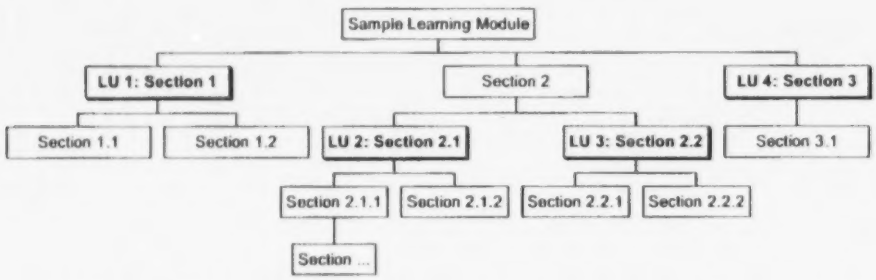

***Figure 1:** Hierarchical sequential organisation of a learning module in sections and learning units*

We organise a learning module hierarchically in sections according to the logic of the instructions to be presented, **and** sequentially according to the identified learning units [R99]. The logic of instruction corresponds to the skills of the target group identified in the analysis of situated items.
Note: We do not assume that there is only one possible hierarchical, sequential organisation of a module. Different organisations may be defined manually or automatically according to the learner's prerequisites, amount of study time and individual objectives. However, for a given instance of a learning module we suggest an ordered tree as the appropriate organisation.

Horizontal Micro Structures – Information Model of Learning Unit

In this section we present the horizontal organisation of learning units due to a sequential order of didactical units in contrast to the vertical organisation discussed in the next section.

A learning unit consists of two basic concepts: didactical metadata and didactical units.
Didactical metadata contains helpful information about a learning unit to support the learner in finding the appropriate learning unit, getting started with learning and navigate efficiently through the presented material according to individual objectives. On the authoring side, didactical metadata serves as an abstract specification of the learning unit stating its objectives and relationships to other learning material, the user profile, and the external learning environment.
Didactical units represent the instructional content to be worked through by the learner. They implement the instructional design of the learning unit. Didactical units are ordered sequentially within a learning unit.

Content units in our context are chunks of information of any granularity and any type. Didactical units and their substructures **are** content units and may **contain** further sub-units at a lower level of granularity.

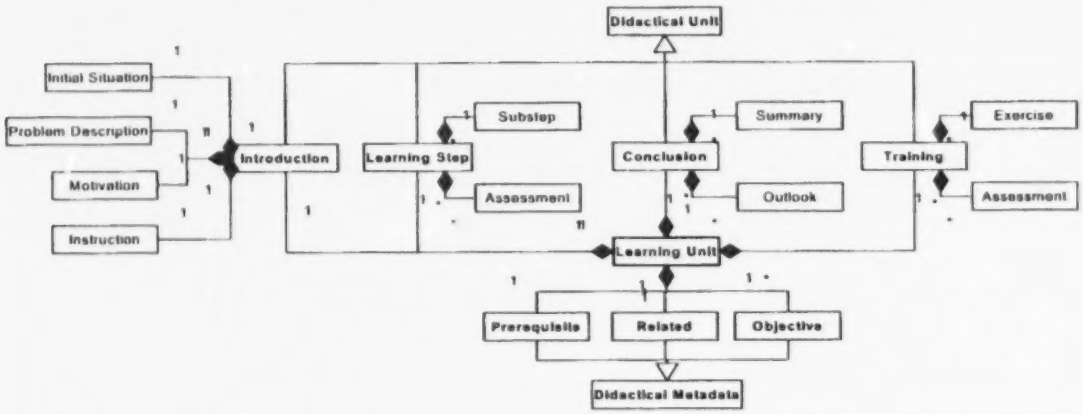

Figure 2: Information model of a learning unit

Didactical Metadata

We propose three categories of didactical metadata supporting the orientation of the learner.

- **prerequisites**: requirements concerning the learners profile (knowledge of certain material and keywords, level of mastery of previous objectives).
- **objectives**: learning targets of the current learning unit according to Bloom's taxonomy (knowledge, comprehension, application, analysis, synthesis, evaluation) [B56].
- **related** material: references to material which is in any sense related to the content of the current learning unit or the process of working through it. The target of these references can be internal (within the current learning module) or external (e.g. other web sites), online (URLs) or offline (e.g. books), content (web sites, books) or software (tools, simulators, programming environments) or physical elements (e.g. tools for conducting an experiment).
  Categories of related material are resources (references or tools necessary or helpful to work through the current learning unit), continuations (possibilities to continue the study besides the immediately following learning unit), extensions (references to material which extend the content of the current learning unit, and generally related material (study material with similar content, objectives or focus).

Objectives play a central role in the didactical design of learning units. According to the general model of instructional design we suggest to specify the objectives of a learning unit first before specifying its didactical units. When specifying didactical units the objectives are linked to the relevant content units or test questions within the learning unit. Thus a bipartite graph as depicted in figure 3 is defined between content units and associated objectives [G89].

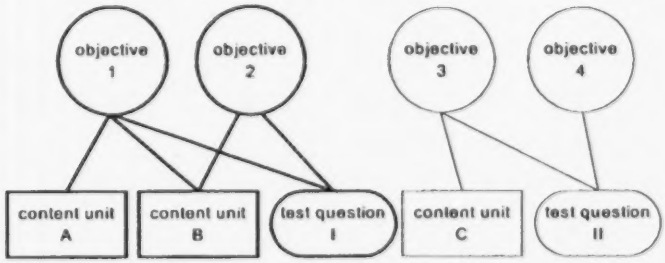

Figure 3: Bipartite graph of objectives and units of contents / test questions

Regarding the manifold functions of objectives we refer to the discipline of instructional design [M94] and add the following:

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- Objectives - when associated with content units - can serve as an additional, goal oriented navigation structure.
- They serve as an indirect association mechanism between different content units as well as between content and test questions. Content units associated with the same objective are similar according to this objective. This is particularly useful in relating test questions to relevant content. In figure 3 the relevant text passages for test question 1 are content unit A and B. If the learner has problems in answering this question the test system can direct him/her to the related material.
- As stated previously, objectives can be interpreted as an abstract specification of the learning unit. The association between objectives and content to some degree enables the formal verification of a given implementation. In figure 3 objective 4 is not associated with any content unit, thus there is obviously no course material present which could enable the learner to achieve objective 4. A processor examining the associations between objectives and content can automatically identify these possible structural problems.

Didactical Units

Didactical units implement the instructions of a learning unit w.r.t. its objectives. They contain

- **overview information** presented in the introduction and conclusion.
- **detailed information** about the concepts to be studied as presented in the learning steps.
- **exercises** and **test** questions presented in the training section.

The aim of the **introduction** is to (1) **get** the learner **started** by stating the textual context of the current learning unit within the module (initial situation), (2) **activate** the learner by defining the problems to be solved within the current learning unit (problem description), (3) **motivate** the learner (motivation), and (4) **guide** the learner by giving specific instructions of how to work with the following material (instruction).

Learning steps present the details of the concepts to be learned. We suggest to divide the material of a learning unit into 3 or 4 learning steps each about 10 to 15 minutes in length as this is about the average attention span for picking up new information on the screen [KS89]. A learning step is divided into a small number of substeps. After working through the substeps the user is directed to an assessment screen containing a small number of relatively simple self test questions. These questions activate the learner and provide regular and immediate feedback regarding the learning progress.

The **conclusion** puts the details presented in the learning steps into an overall context of the learning unit by (1) **repeating** the essence of the concepts studied in the previous learning steps (summary), and (2) **motivating** the learner to continue studying the following learning unit (outlook).

The **training** part plays a central role in learning. Its aims are:

- Building up a high level of mastery of the defined objectives through active reproduction and application of the concepts studied in the learning steps (exercise).
- Self-test and feedback regarding the degree of mastery of the objectives (assessment).

It may be desirable that some exercises such as formal proofs, programming or software design are done offline or using specialized tools. While these exercises can be listed in the exercise section of a learning unit the execution, submission, assessment and feedback is out of the scope of the model.

Current e-learning and CBT systems provide a large variety of tools and information models for computer based online/offline training and assessment [QTI02]. We do not suggest yet an another information model but assume, that one of the existing formats is adopted according to local requirements (installed e-learning platform and assessment tools). The entities exercise and assessment in our information model serve as an abstract placeholder for one of these local information models.

Presentational Design

Presentational design adds annotations to the didactically structured material such that the material can be optimally presented as web-pages with respect to the special limitations (low information density) and advantages of the medium web (linking, interactivity).

Presentation Units

The concepts presented so far were merely motivated by the didactical function of the content. Presentation units are motivated by the characteristics of the medium web. A **presentation unit** represents the content of one single web page. Its size should be small enough to avoid scrolling [B97].

Ideally, presentation units can be defined along didactical structures such as introduction, substep, or summary. However, it might be appropriate that a complex substep spans several presentation units or that several small substeps are covered by a single presentation unit.

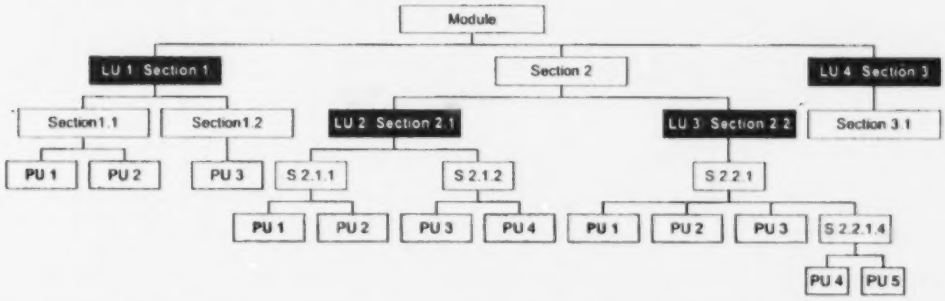

***Figure 4**: Hierarchical sequential structure of a learning module after definition of presentation units*

The module is organised as an ordered tree having presentation units as leaf nodes. Sequential orders are defined at the level of learning units and at the level of presentation units within learning units. This two-level sequential order serves as an ideal address base. Every page within the learning module can be identified by two numbers: the number of the learning unit and the number of the presentation unit within the learning unit. This is useful for the **orientation** of the learner ("Where am I?") and for precise **communication** for example in giving feedback ("Don't understand definition in LU 3 / PU 5").

Vertical Micro Structures – Presentation Levels

Besides the didactical function of content we identify two subsidiary structural dimensions: (1) **importance** of content regarding the objectives to be achieved, and (2) **difficulty** of material for the average learner.
Related to these dimensions we can define three distinct *presentation levels* as follows:

- Content units, which are important and relevant regarding one or more objectives, belong to the presentation level **basic**.
- Content units, which are less important or relevant **and** can be assumed to be known or self explanatory for the majority of the target group (low difficulty), belong to the presentation level **help**.
- A content unit is assigned the presentation level **extension** if it is less important **and** difficult to understand for the majority of the target group (e.g. due to its high level of abstraction and formality).

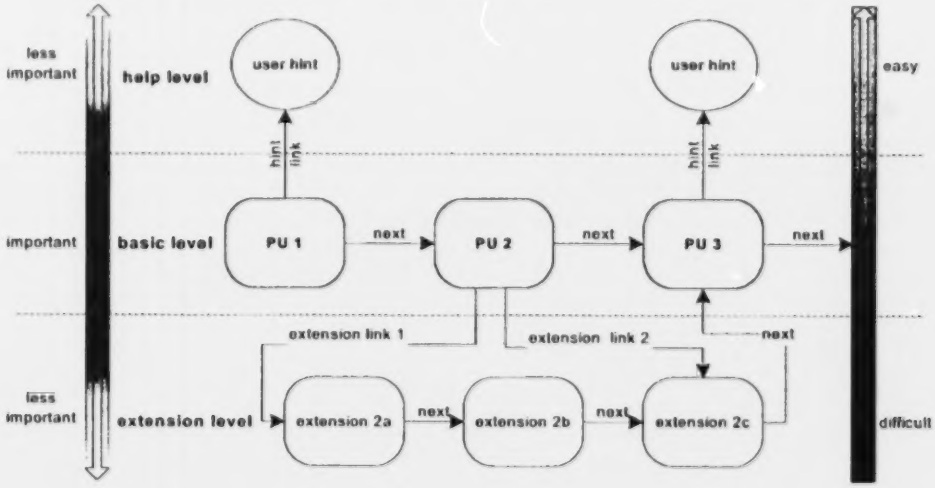

***Figure 5:** Vertical micro structure of a learning module organised by presentation levels*

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By revising the material and assigning presentation levels to content units the following is achieved:

- The content of the basic presentation level is concise and highly focussed on current objectives.
- The novice user can access additional information at the help level on demand.
- The experienced or specifically interested user is offered additional opportunities in deepening his / her knowledge by pursuing extension links.

4. Related work

Pedagogical theories and models proposed in the literature are manifold [K01]. As a result existing formal models of courseware take up a rather abstract point of view in order to be valid for all kinds of learning situations and didactical strategies.

The CAMELEON project aims at providing reusable modules for online/offline course materials encoded in TeachML [WL01]. TeachML identifies several didactical units (such as examples, figures with explanation, exercises) and structures such as (courses, chapters, learning paths, ...). However, an underlying didactical model or design strategy is not visible. As a result TeachML gives little assistance in *how* to use the provided elements in order to develop learning material which can optimally be presented and studied on the web.

The "life long learning" project aims at meeting the needs of different target groups by offering several learning trails through the same online course specified in the XML language L3-XML [SLK00]. L3-XML introduces the notion of a learning unit (LU). Similar to our approach each LU contains objectives and all information necessary to achieve them. However, in L3-XML a LU is a recursive element in order to specify the hierarchy of topics presented in a course rather than a precise didactically motivated information model for a single learning session.

The EML [K01] provides a framework for the complete XML-based description of all objects, roles and activities involved in the teaching/learning process of a unit-of-study. EML is an XML-binding of a pedagogical meta model and thus stays abstract regarding the specific instructional / pedagogical model to be adopted when implementing a unit-of-study. Our specific didactical model can serve as a possible instantiation of the EML meta model for cognitively organised instructional material. It can be integrated into EML (and other existing mark-up languages) by using subtyping as suggested in [K01] and already successfully implemented on the basis of LMML [SFB99, WSK02].

5. Conclusion

We presented a reference model for structuring online modules in formal and abstract domains such that the learning content can be optimally presented according to the characteristics of the medium web. We have shown how to tackle two problems inherent to web based material – loss of overview and short attention spans – by satisfying the following structural requirements: (1) *first present the overview then the details* (introduction), (2) *restrict yourself to significant information* (presentation levels), (3) *offer orientation opportunities* (two level sequential order of learning units and presentation units), (4) *provide contextual information* (introduction, summary, objectives associated to each presentation unit), (5) *Don't present too much at once* (small learning units, learning steps and presentation units), and (6) *regularly activate the learner* (each learning step of 10-15 min ends with a self-test).

Our approach is different and innovative as compared to other approaches because

- we identify the didactical components of courseware on the microstructure level and suggest precise qualitative and quantitative guidelines based on research results.
- we distinguish three presentation levels as an additional dimension of structuring online material, which help to focus on essential information while maintaining the formal completeness of the material.
- we do not only introduce didactical metadata such as objectives as useful concepts in organising and managing learning material, but also suggest association of objectives and learning content/exercises to provide a goal-orientated navigation facility and to define indirect associations between single content units of the learning module.

An XML-Binding of our model is currently integrated as a possible didactical component into the LMML and WWR-ML frameworks [SFB99, Dea02].

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